SCB Workshop Topic Proposal: Modularity and Its Origins

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What topics will the review address?

First, this review would address attempts to create unified definitions of modularity across different fields and to measure modularity quantitatively, as in order to understand the origins of modularity, we have to know what modularity is. It would cover Bolker's definition of modules across different subfields of biology, Schilling's comparative study of what is considered to make a system modular in several different fields, and the differences, also described by Bolker, in how evolutionary biologists tend to perceive biology (as morphological) vs. how developmental biologists tend to perceive it (as functional). It would give an overview of modularity metrics like the Newman-Girvan algorithm (commonly used in artificial life studies of modularity) and the Louvain algorithm.

Then, it would examine research on the origins of modularity. This would include, among others, Wagner and Altenberg's early work on natural selection and modularity, Kashtan and Alon's modularity varying goals hypothesis, Clune et al's work on connectivity cost and modularity, and Lowell's paper (to be presented at ALIFE 15) on development and hierarchical modularity.

Finally, it would cover potential applications of this research, including automated robotic design, systems microbiology, bioengineering, and greater understanding of brain disorders (see Fornito et al, 2015, in Nature Reviews Neuroscience).

Which subfields will the review bring together?

Modularity is an important concept in many different fields. The subfields that this review will bring together include:

Engineering: Robotics, engineering design

Physics: Biophysics, condensed/soft matter physics, statistical and nonlinear physics

Biology: Evolutionary biology, developmental biology, microbiology, neuroscience, systems biology

Other: Artificial life, complexity science

How will synthesizing these bodies of research benefit the field(s)?

Right now, there are multiple communities of researchers working on issues of modularity who don't often interact with each other. For example, the 2016 American

Physical Society March Meeting had multiple presentations on modularity, but few computer scientists attend the March Meeting (and few physicists attend computer science conferences where modularity is discussed). Experimental biologists who observe modularity in their model systems may not be aware of the body of theory that exists on modularity, and how it might be relevant to their work, while theorists may not realize possible applications of their work. Many algorithms for quantifying modularity come from the physics and complexity communities, and those in other communities may not be aware of progress, or indeed different options, in detecting and quantifying things like communities within networks.

Examples of terms and/or concepts used differently across the fields:

An example of such a term is modularity itself. Earlier in this proposal, I mentioned that evolutionary biologists tend to see modularity as a morphological component, e.g. of an organism, while developmental biologists are more likely to think of a module as a combination of components that operate together to perform a function. In addition, while most fields, according to Schilling (2002) define hierarchical nesting as an important aspect of modularity, artificial life studies of modularity and its emergence have largely ignored this, focusing on the emergence of single-level morphological modularity.